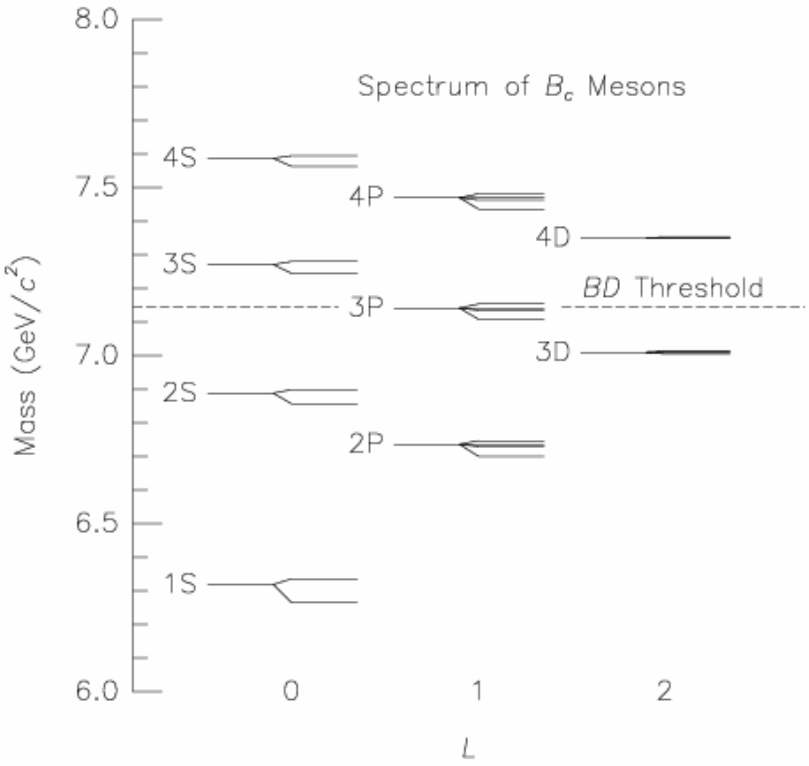
Properties of B_c Meson

On behalf of DØ Collaboration

Dmitri Tsybychev, SUNY at Stony Brook,

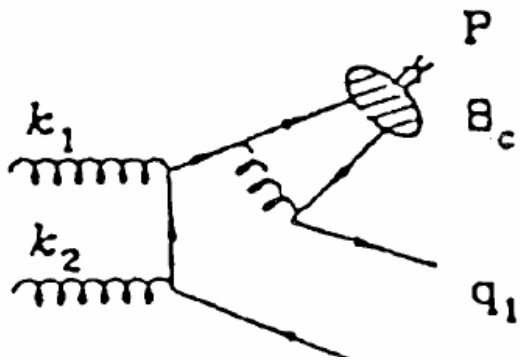
PANIC05, Santa Fe, New Mexico

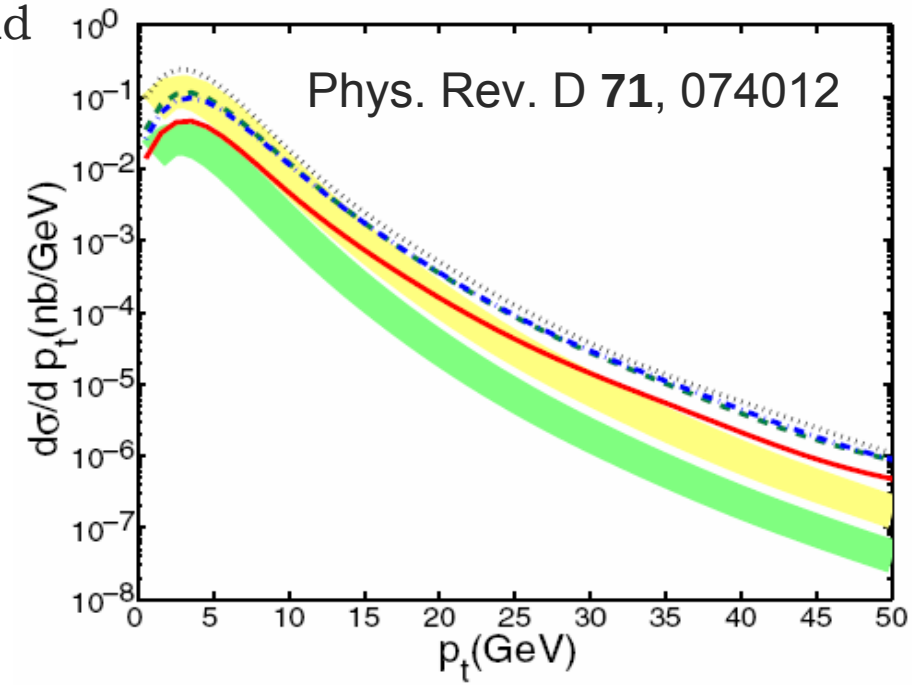
- B_c is ground state of $\bar{b}c$ system
  - Unique system with two heavy quarks of different flavor
  - Probes heavy-quark theories in the region between the cc and bb
  - m_{exp} = 6400 ± 390 ± 130 MeV/c^2 (first observation Bc →J/ψμX CDF Run I, PRD 58, 112004)
  - m_{exp} = 6287.0 ± 4.8 Mev/c^2 (CDF Run II, B_c →J/ψπX)
  - $\tau_{exp}=0.46^{+0.18}_{-0.18}\pm 0.03$ps
  - m_{theor} = 6304 ± 12 $^{+18}_{-0}$ Mev/c^2 (lattice QCD, PRL 94, 172001)
  - τ_{theor}=0.4~1.4 ps



B_c Production at Tevatron

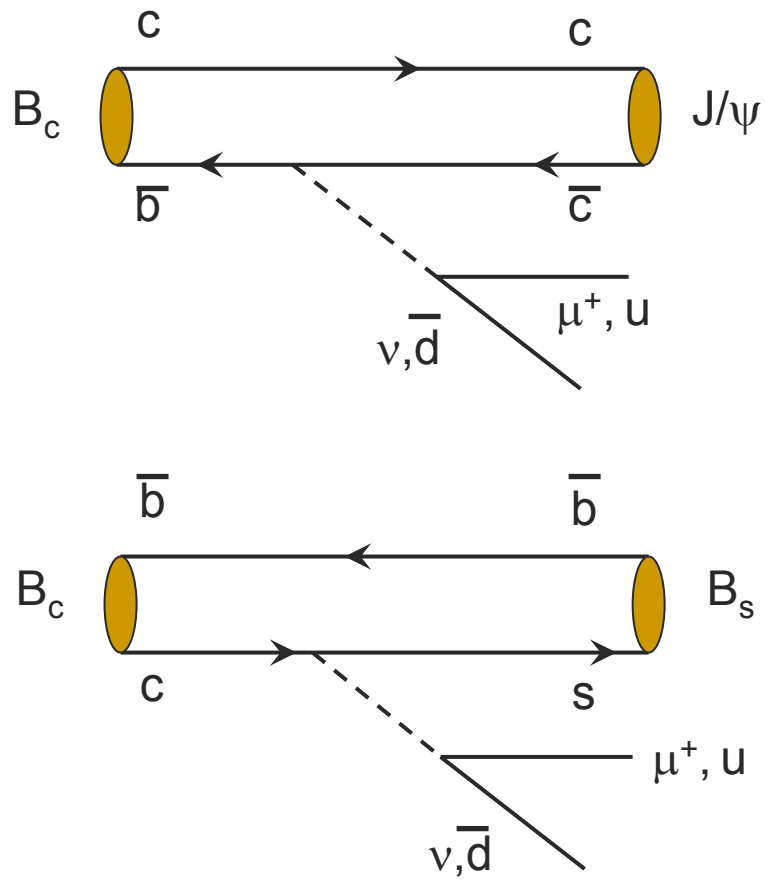
- B_c production cross section:
  - $qq, gg \rightarrow B_c + b + \bar{c}$
  - Sum of production cross sections of ground and excited states
  - Contribution from color-singlet and color octet states
- $\sigma(B_c)/\sigma_{inel} \sim 10^{-6}$
  - Trigger is important





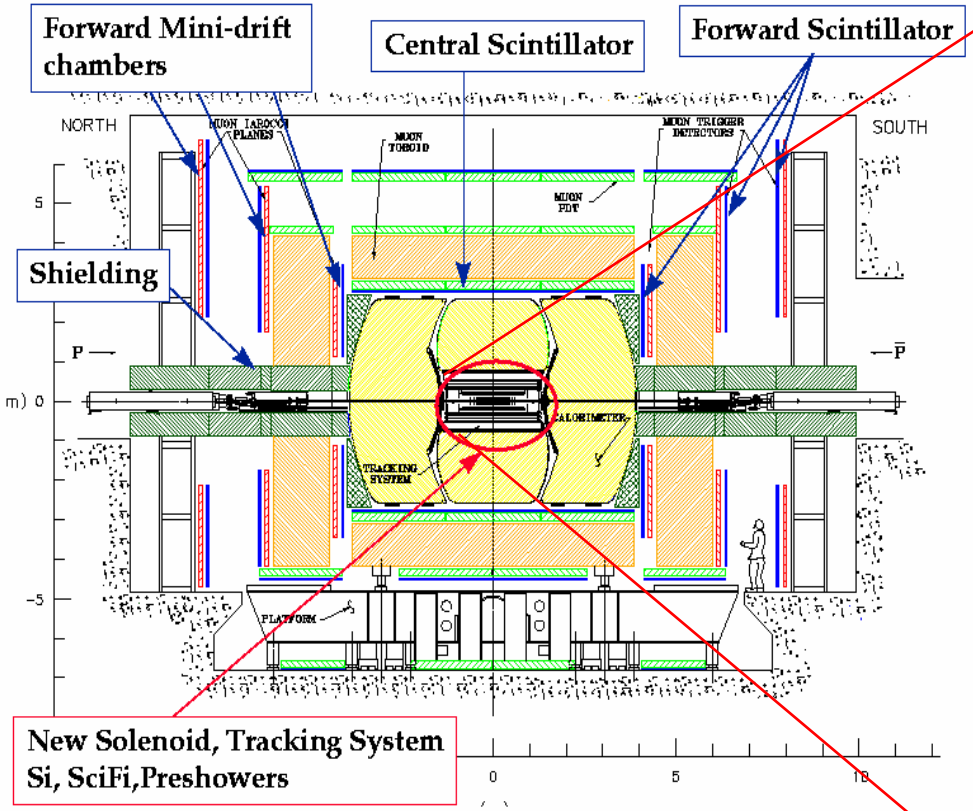
Decays of B_c

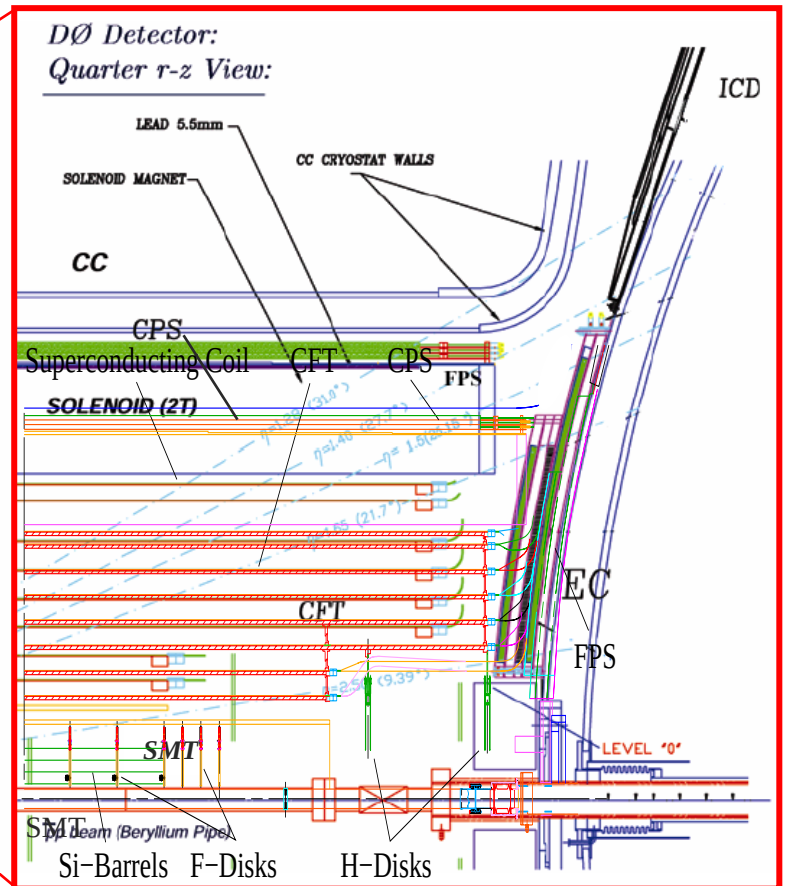
- B_c decays through weak interactions
  - $\bar{b}$-quark decay with a spectator c quark
    - $B_c \to J/\psi\ \mu X$, $B_c \to J/\psi\ \pi X$
    - Observed at Tevatron
    - J/ψ final state is distinctive signature, useful for trigger and reconstruction
  - c-quark decay with a spectator $\bar{b}$
  - The annihilation decays $b\bar{c} \to l\nu, c\bar{s}, u\bar{s}$
  - Charge conjugation assumed
- Searched for B_c in 210 pb^{-1} inclusive J/ψ data sample collected by DØ



DØ Detector

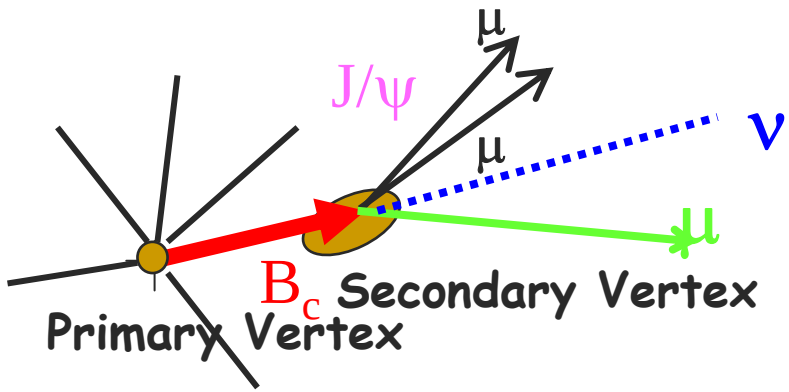
- Excellent coverage of Tracking and Muon Systems
  - Forward muon system with $|\eta|<2$ and good shielding
    - 60% pure at L1 trigger
  - 4-layer Silicon and 16-layer Fiber Trackers in 2 T magnetic field

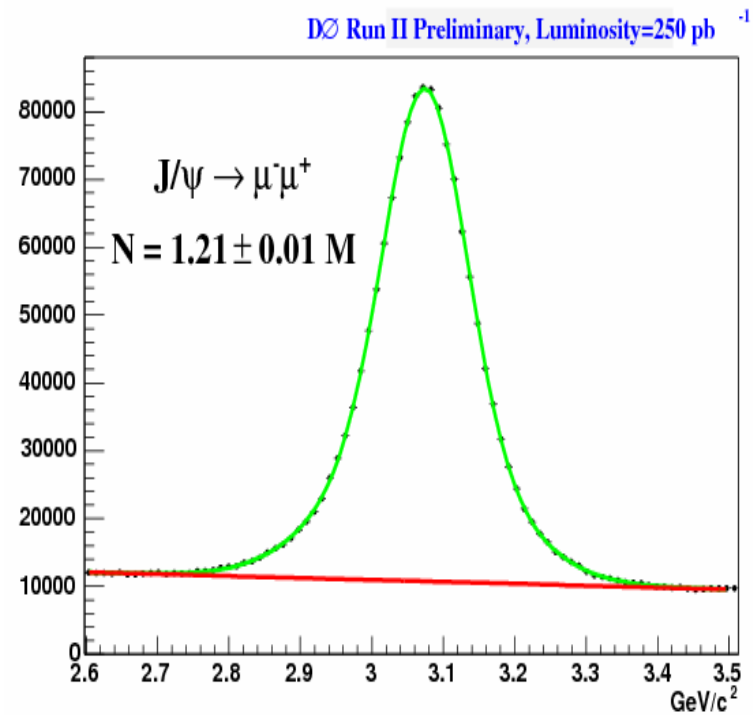




Bc signal

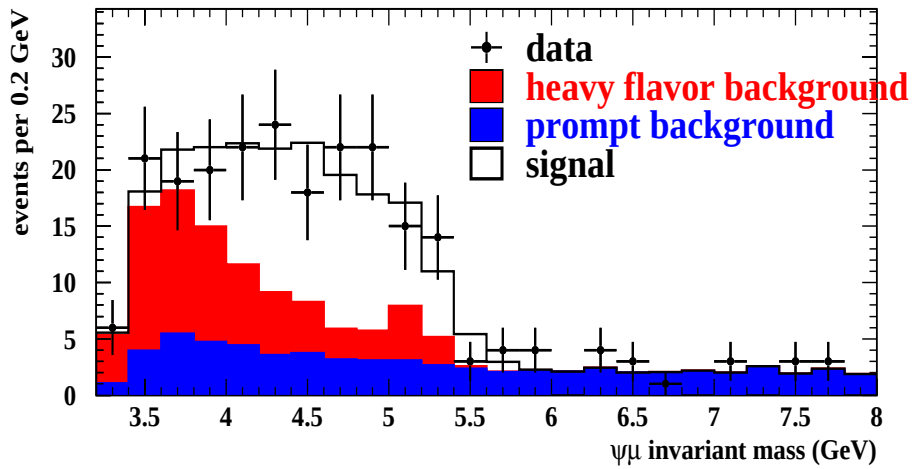
- Use tri-muon final state
  - $J/\psi \rightarrow \mu\mu$ and tight third muon form a vertex
  - 231 $J/\psi\ \mu\ X$ events selected
- Include contributions to signal from
  - Feed-down from $B_c \rightarrow \psi(2S)\ \mu\ X$
  - $B_c \rightarrow J/\psi\ \mu\ \pi^0\ X$
- B_c not fully reconstructed (neutrino)
  - Estimate from control J/ψ + track sample
  - Prompt J/ψ + random or fake muon (prompt background)
  - J/ψ from B decay + random or fake muon (heavy flavor background)

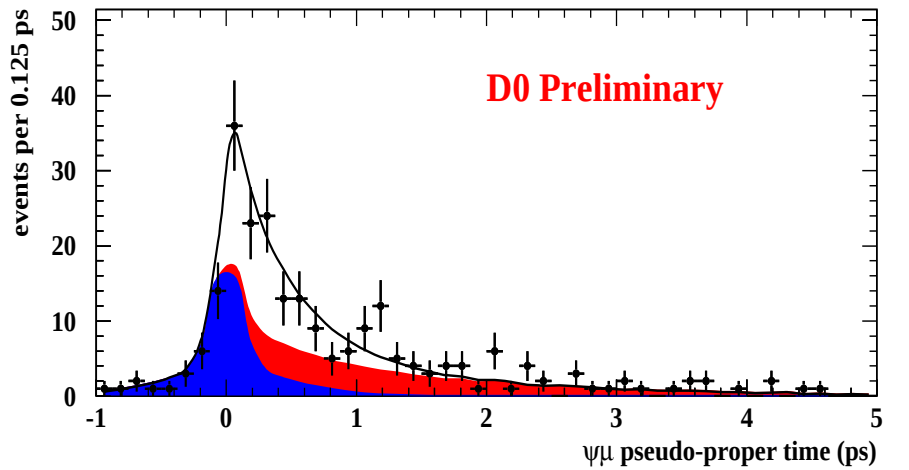




DØ Observation of Bc→J/ψμX

- Plot invariant mass of three muons and pseudo-proper time
  - Not exclusive reconstruction
  - Use MC to get mass template shapes
- Background probability density is obtained from control sample
  - T < 0 – prompt background
  - Symmetric distribution about 0 subtracted off to get
  - T > 0, 2 – heavy flavor background
- Clear excess at higher mass
- Do likelihood fit to pseudo-proper time distribution in invariant mass bins
- Number of B_c candidates: 95 ± 12 (stat.) ± 11 (sys.)





Fit Results

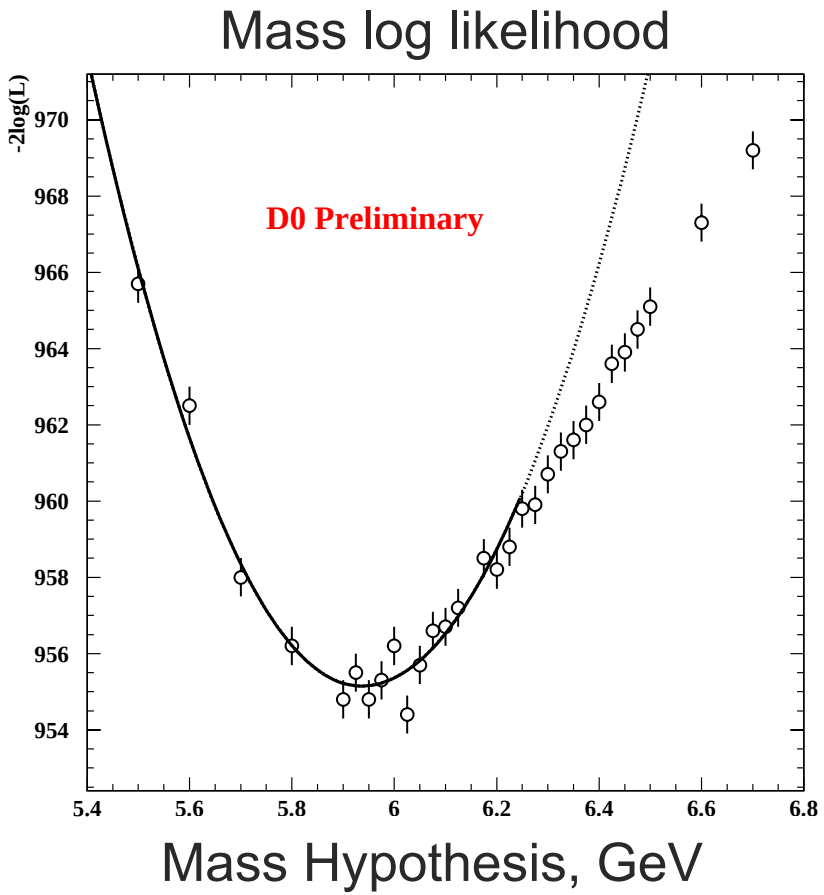
- Mass:

$5.95^{+0.14}_{-0.13}$ (stat.) ± 0.34 (syst.) GeV/c^2

- Lifetime:

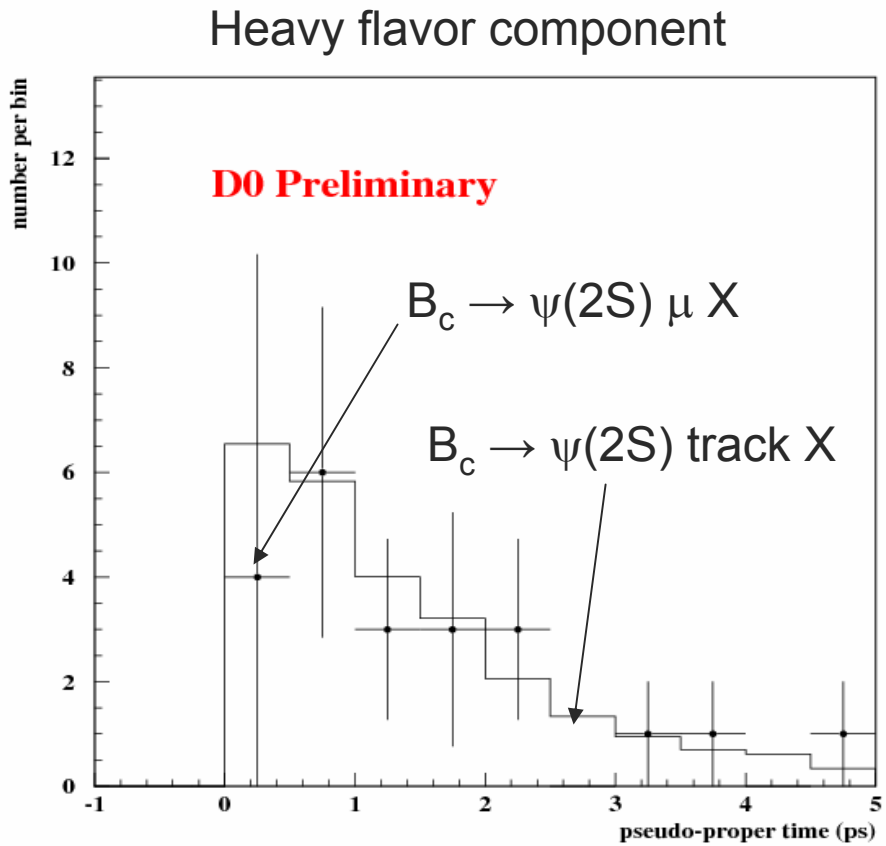
$0.448^{+0.123}_{-0.096}$ (stat.) ± 0.12 (syst.) ps

- Main systematics
  - Mass: signal sample composition, MC signal modeling, fraction of prompt background
  - Lifetime: Bias from vertexing algorithm, fraction of prompt background



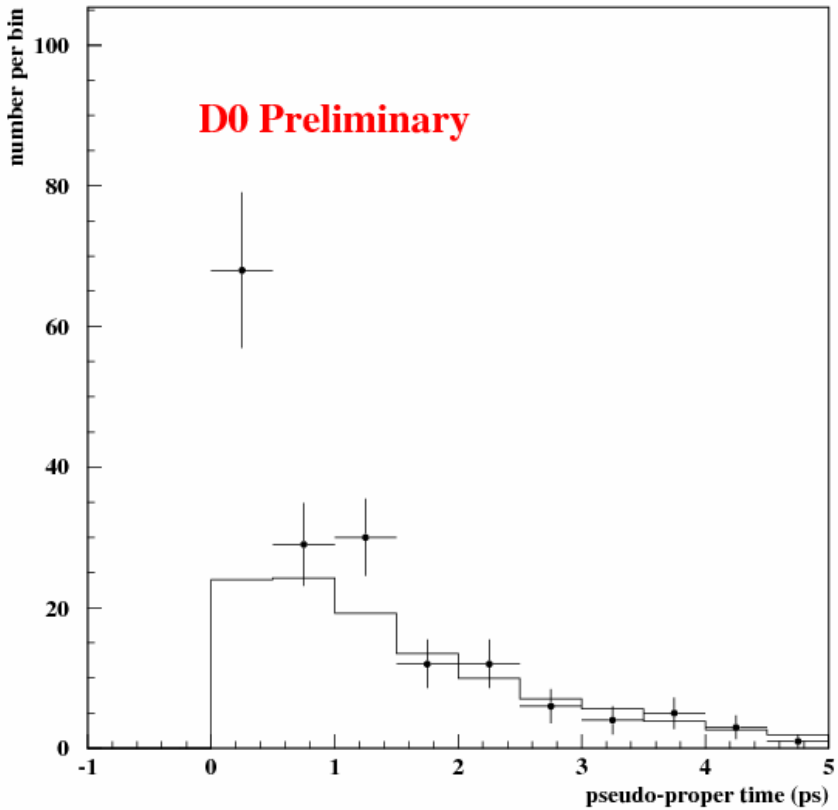
Heavy Flavor Background Check

- Expect $B_c \rightarrow \psi(2S)\,\mu\,X$ be dominated by background
- $B_c \rightarrow \psi(2S)\,\mu\,X$ ~ 5 to 100 times smaller than $B_c \rightarrow J/\psi(2S)\,\mu\,X$
  - Compare $B_c \rightarrow \psi(2S)\,\mu$ sample to $B_c \rightarrow \psi(2S)$ track sample
  - Test of heavy flavor background



Counting Analysis

- Perform a simple counting experiment
  - Normalize background from the control sample
    - Use region with pseudo-proper time > 2 ps
  - 183 candidate events in heavy flavor component
  - 65 ± 26 signal events

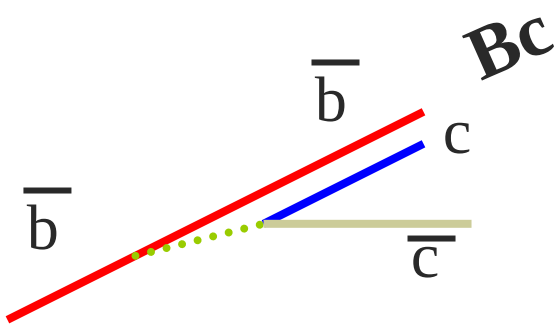


Systematic Uncertainties

Source	Mass (GeV/c^2)	Lifetime (ps)	# Signal
Limited background statistics	0.06	0.013	3.0
Fraction non-resonant $B_c^+ \to J/\psi\mu^+\pi^0\nu$	0.14	0.022	6.7
Feed-down fraction from $B_c^+ \to J/\psi(2S)\mu^+\nu$	0.08	0.017	5.4
MC signal modeling: phase space vs. ISGW	0.16	0.023	4.4
MC signal modeling: HQET vs. ISGW	0.06	0.007	1.8
B_c p_T spectrum	0.05	0.004	0.8
Momentum binning	0.14	0.062	0.4
Alignment and primary vertexing algorithm	0.08	0.085	3.1
Vertex algorithm selection criteria	0.06	0.028	–
Prompt/heavy relative bkgd fraction	0.15	0.036	–
Total systematic error	0.34	0.121	10.7

Other Properties

- Fragmentation process $b \rightarrow B_c + \bar{c}$ dominates production
  - Charm quark should form weakly decaying charmed hadron in vicinity of B_c



- Measured probability to have muon within $\phi \pm 90^o$ of B_c candidate
  - 5 ± 2 % for signal sample
  - 1% for background sample

Conclusions

- Observed $B_c \rightarrow J/\psi\, \mu\, X$ at DØ
- Preliminary results
  - Number of candidates: 95 ± 12 (stat.) ± 11 (syst.)
  - Mass: $5.95^{+0.14}_{-0.13}$ (stat.) ± 0.34 (syst.) GeV/c^2
  - Lifetime: $0.448^{+0.123}_{-0.096}$ (stat.) ± 0.12 (syst.) ps
- Analysis is repeated with much bigger dataset
- Significant progress in $B_c \rightarrow J/\psi\pi$ channel